Simulation and Real-Time Verification of Video Algorithms on the TI C6400 Using Simulink

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Abstact

This talk will show how the use of system-level design tools, such as MATLAB and Simulink, can greatly enhance an engineer's ability to quickly and effectively translate product-level and algorithm-level specifications into a working TI DSP-based prototype for the consumer electronics market. Specifically, we will show how to efficiently target typical video processing algorithms, with the high bandwidth and algorithmic efficiency they require, to the TI C6400 platform, and the value of utilizing simulation test-benches to verify real-time behavior of the final system using TI's High-speed RTDX capability. Both the TI C6416 DSK and the XDS-560 Emulator are demonstrated.

Presentation Structure:

Strength of system-level design (SLD) approach for consumer electronics
Problems in code generation and verification that SLD software can help solve
Introduction to the application of video processing, theory of algorithm design
- algorithm will either be "motion and edge detection" or "iris scan recognition", depending on how lucky we feel for the live demos ;-)

Implementation Details
- Live use of Simulink system-level design software
Automatic code generation, hardware task performance
- Live demonstration of C6400 DSK code generation using MathWorks
- Real-Time Workshop, optimization and real-time execution Design verification and real-time testbenching
- Live demonstration of real-time video data transfer and test-bench verification using RTDX and MATLAB Link for TI DSP

Conclusion
- Vision for future support of video and TI processor family

Report Documentation Page

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See also ADM001694, HPEC-6-Vol 1 ESC-TR-2003-081; High Performance Embedded Computing (HPEC) Workshop (7th)., The original document contains color images.

14. ABSTRACT

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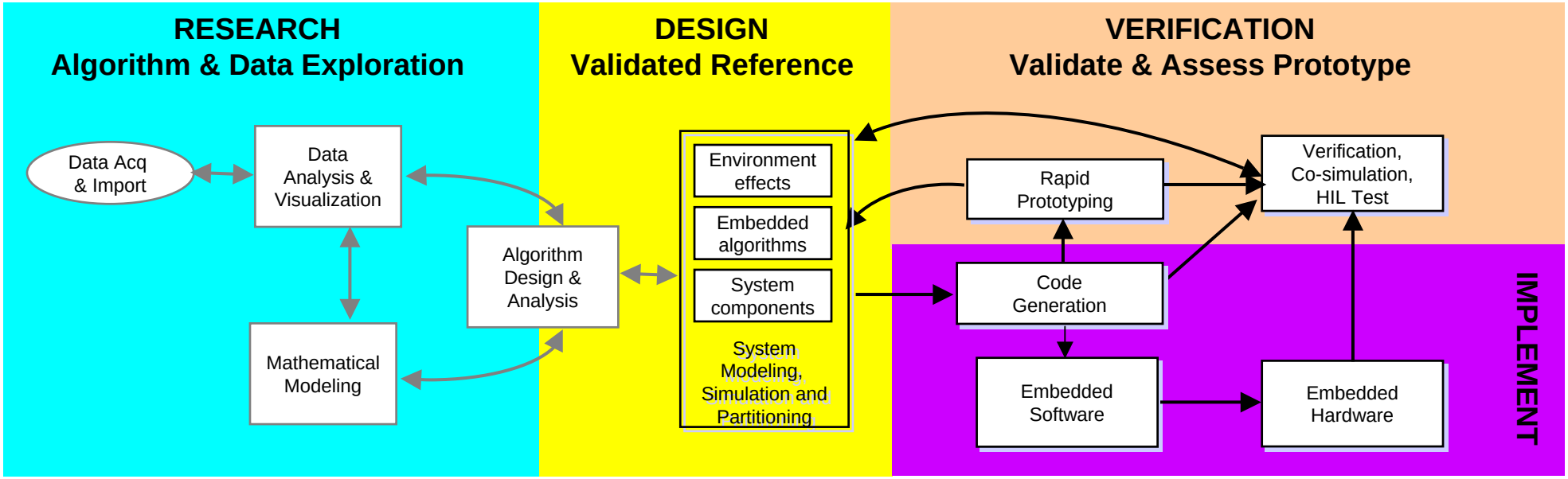
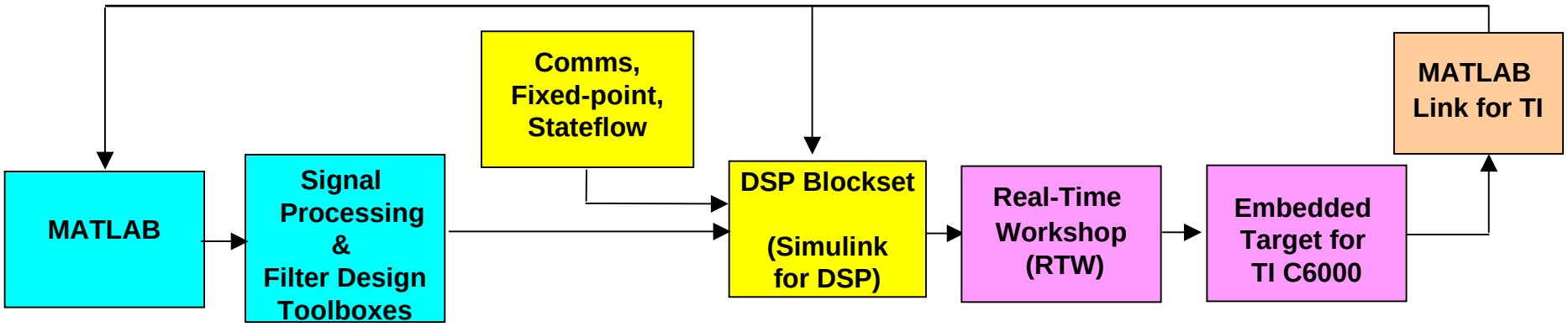
Application: Surveillance Data-Stream Compression

- **Need:** Continuous monitoring of scene with video camera
  - Security (ATM booth, parking lot), Intelligent Highways, Bio/Pharma, etc.
- **Problem:** Generates large volumes of data to record, archive, and review
  - Preferable to reduce data stream at the source (embedded compression)
- **Solution:** Shrink data storage requirements
  - Reduce **size of each** video frame to record, and/or
  - Reduce **total number** of video frames to record
- **Simple Idea: Motion** within camera's field of view **triggers storage** of "interesting" frames

Video Application: Identify and record only these "interesting" video frames

Embedded System Strategy: Model-Based Design

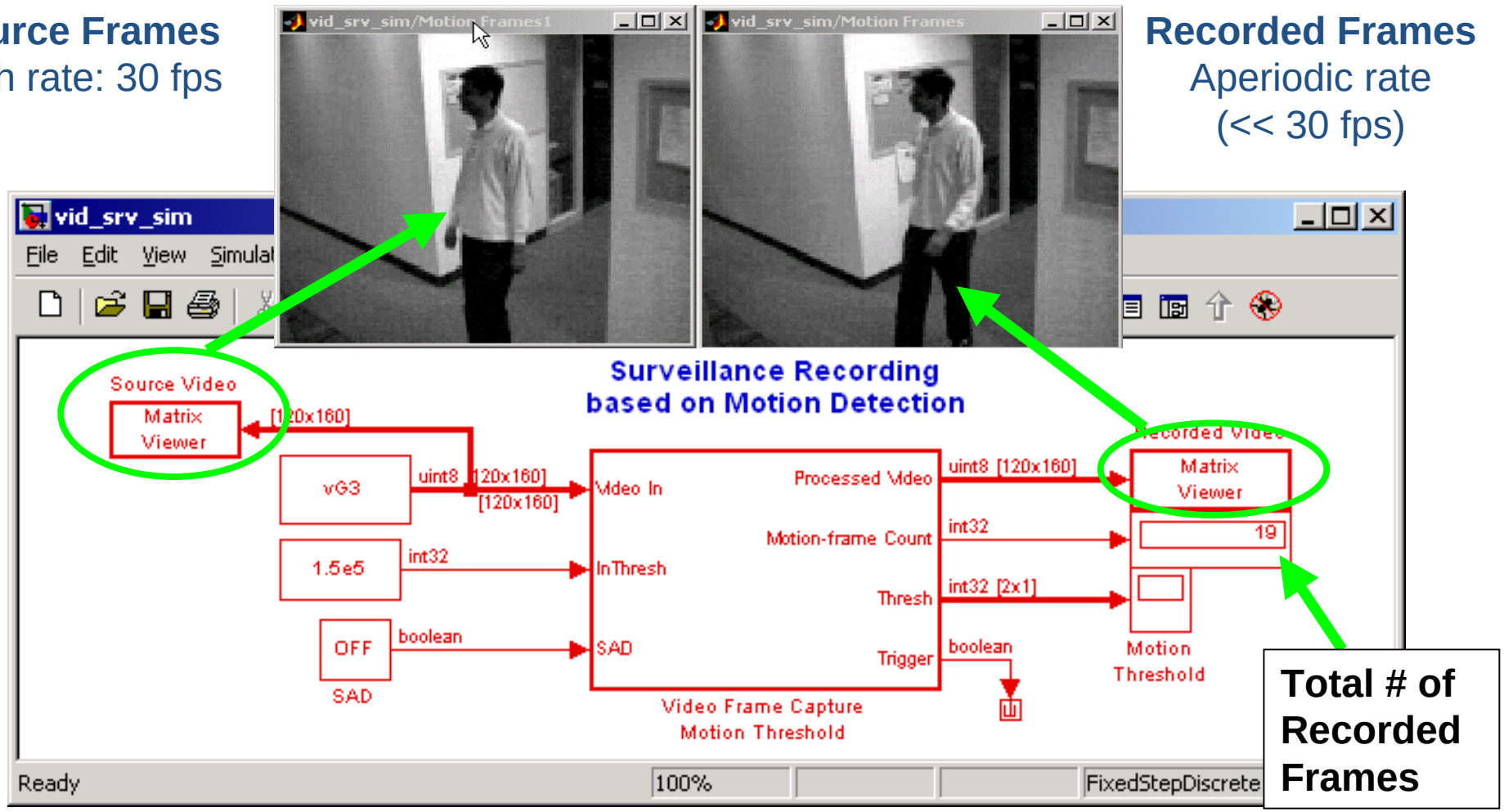




Surveillance Compression

Source Frames
High rate: 30 fps

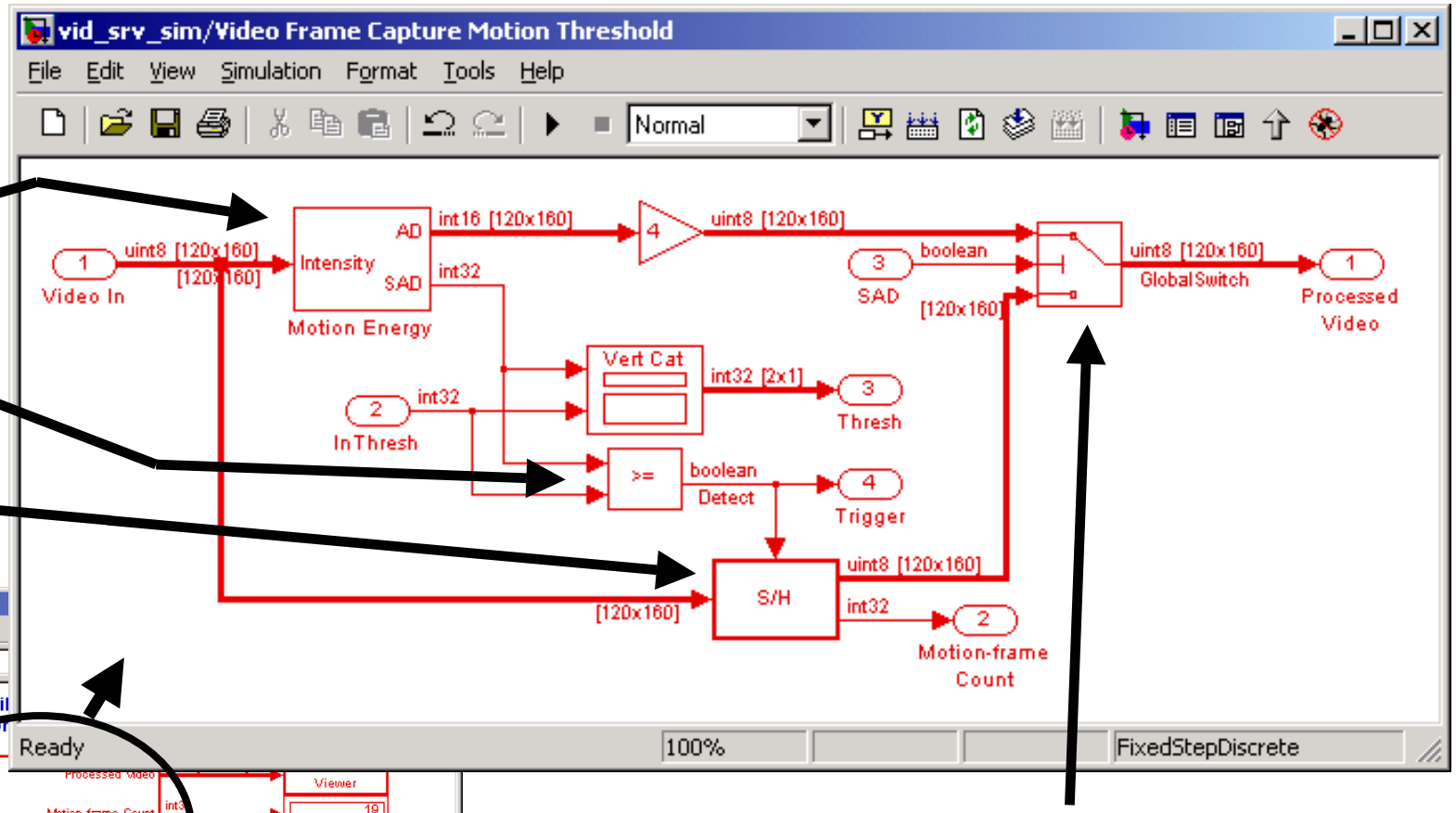
Recorded Frames
Aperiodic rate
(<< 30 fps)

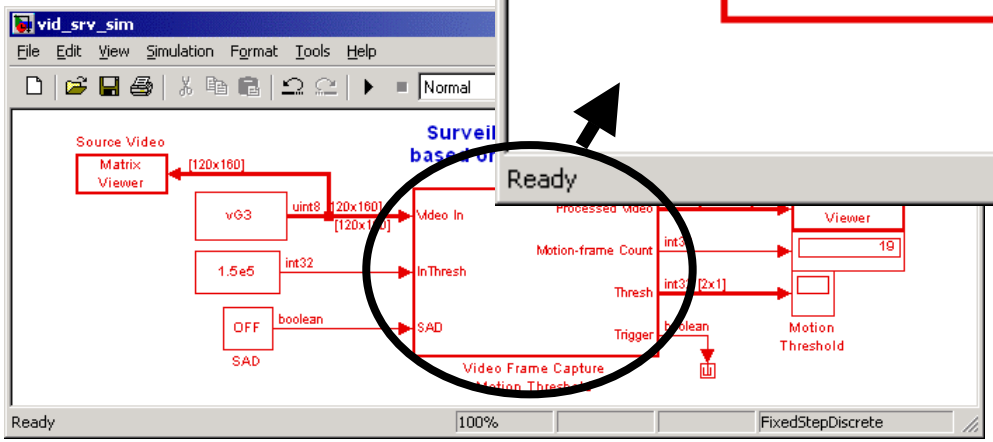


Subsystem Hierarchy

Model Overview

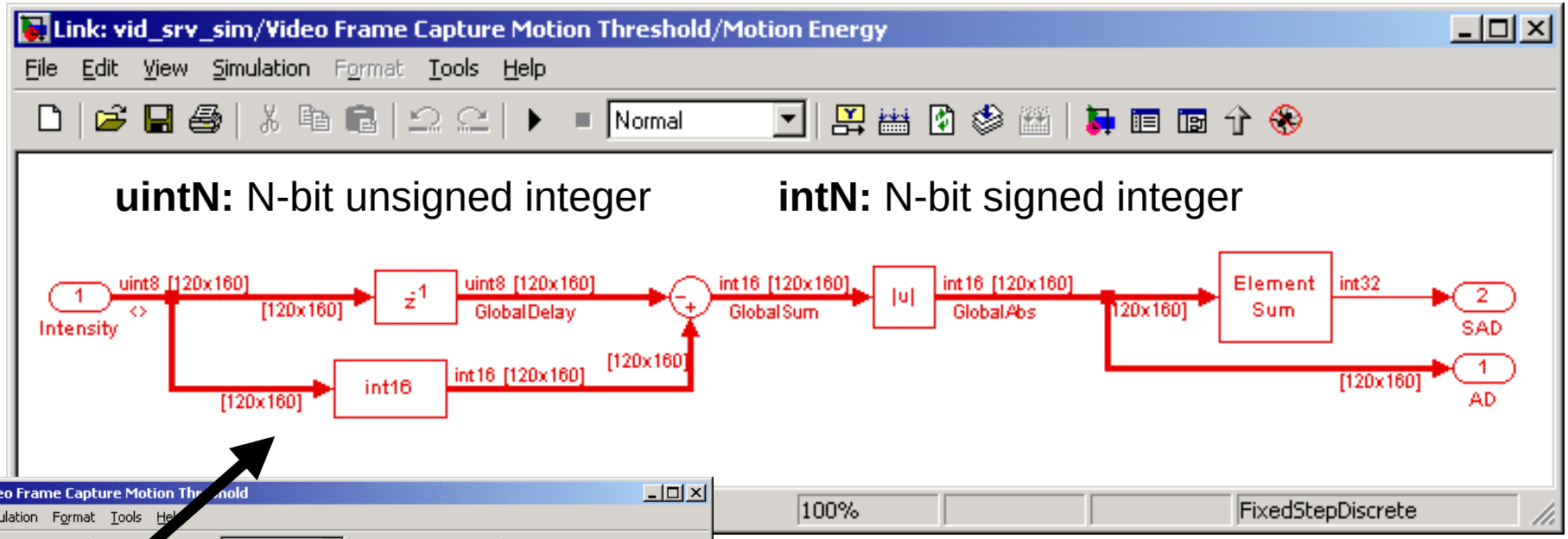
- Estimate motion
- Compare threshold
- Record frames & update count

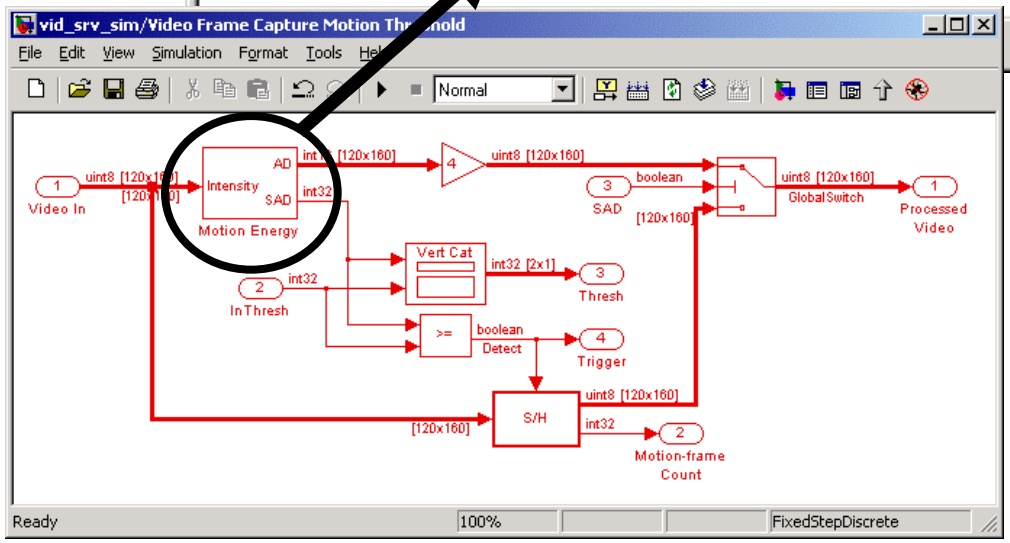




Allows switching between **compressed** and **absolute differences** video streams on-the-fly, for enhanced testing

SAD Algorithm for Motion Estimation

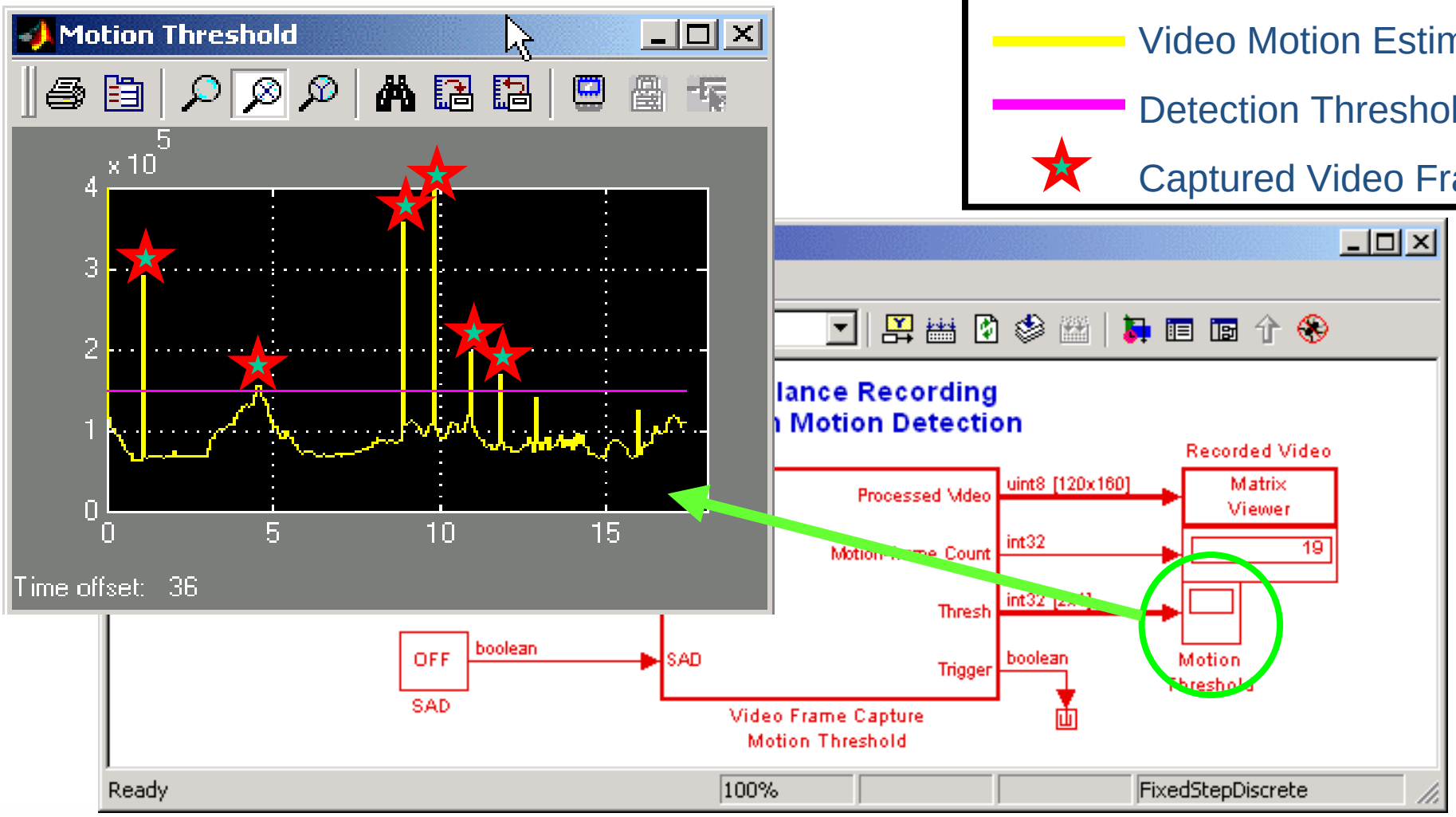




Sum of **A**bsolute **D**ifferences

- Very simple method of inter-frame video motion detection
- Has efficient fixed-point (integer) implementation in hardware

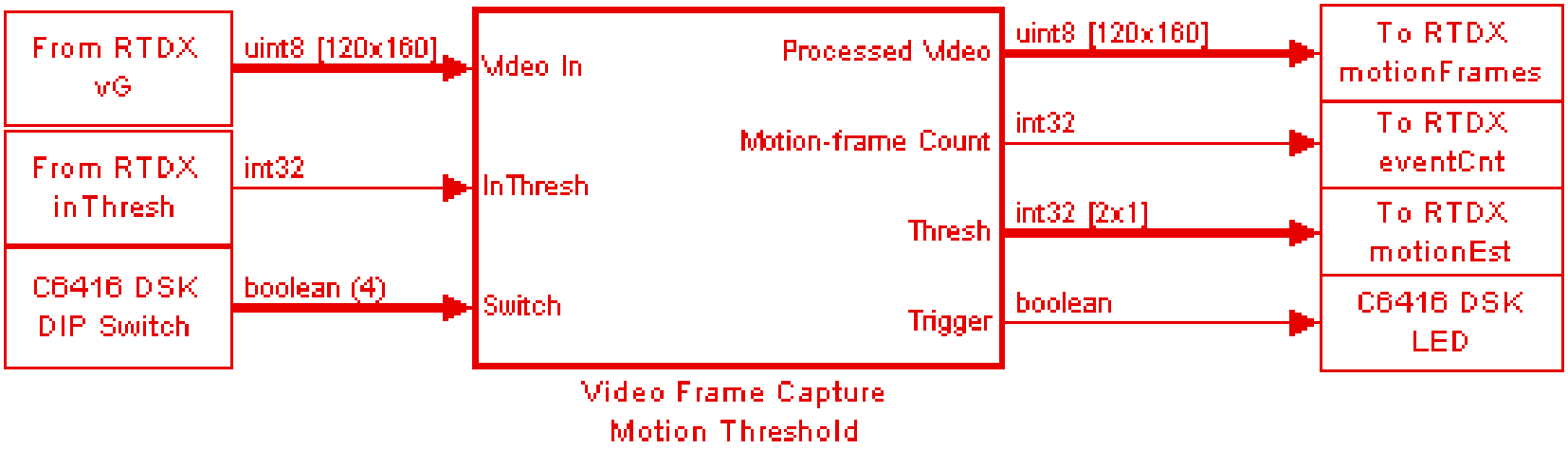
Motion Detection via Thresholding



Steps to Target the TI C6416 DSK

1. Utilize I/O blocks to prepare for on-target system verification

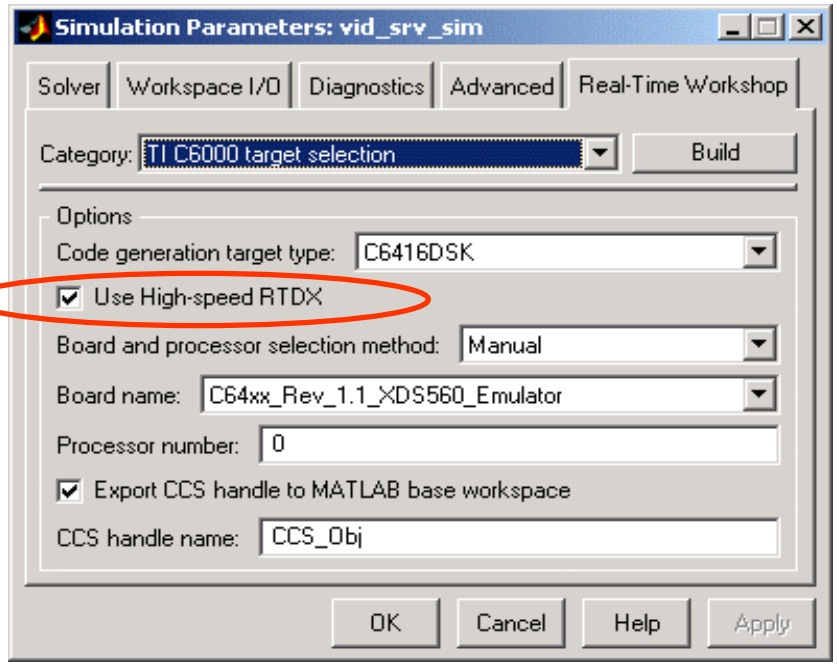
- **Use board support library components, such as RTDX Input/Output, codecs, LEDs, switches, etc**

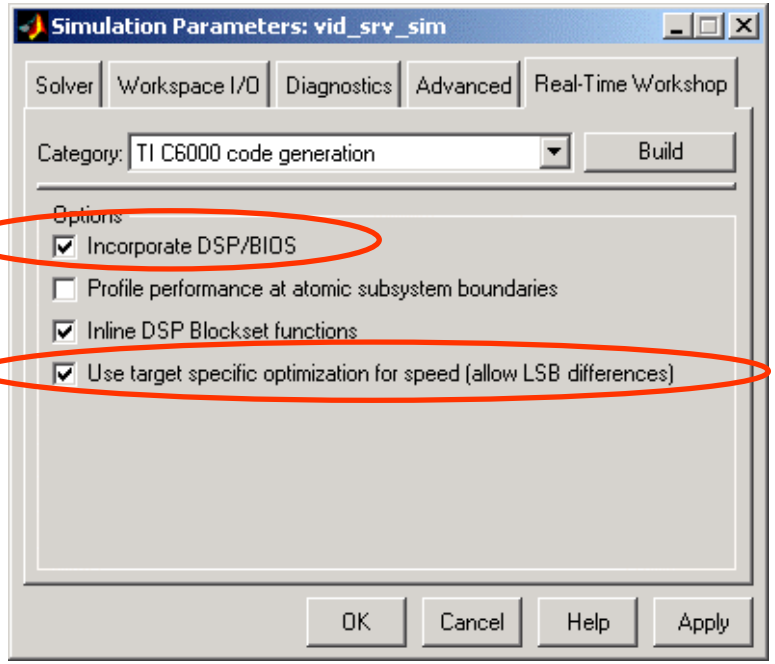


RTDX: TI protocol for Real-Time Data eXchange
High-Speed RTDX offers **~2 MB/sec** bandwidth

Steps to Target the TI C6416 DSP

2. Select target options (DSP/BIOS, compiler settings, etc)

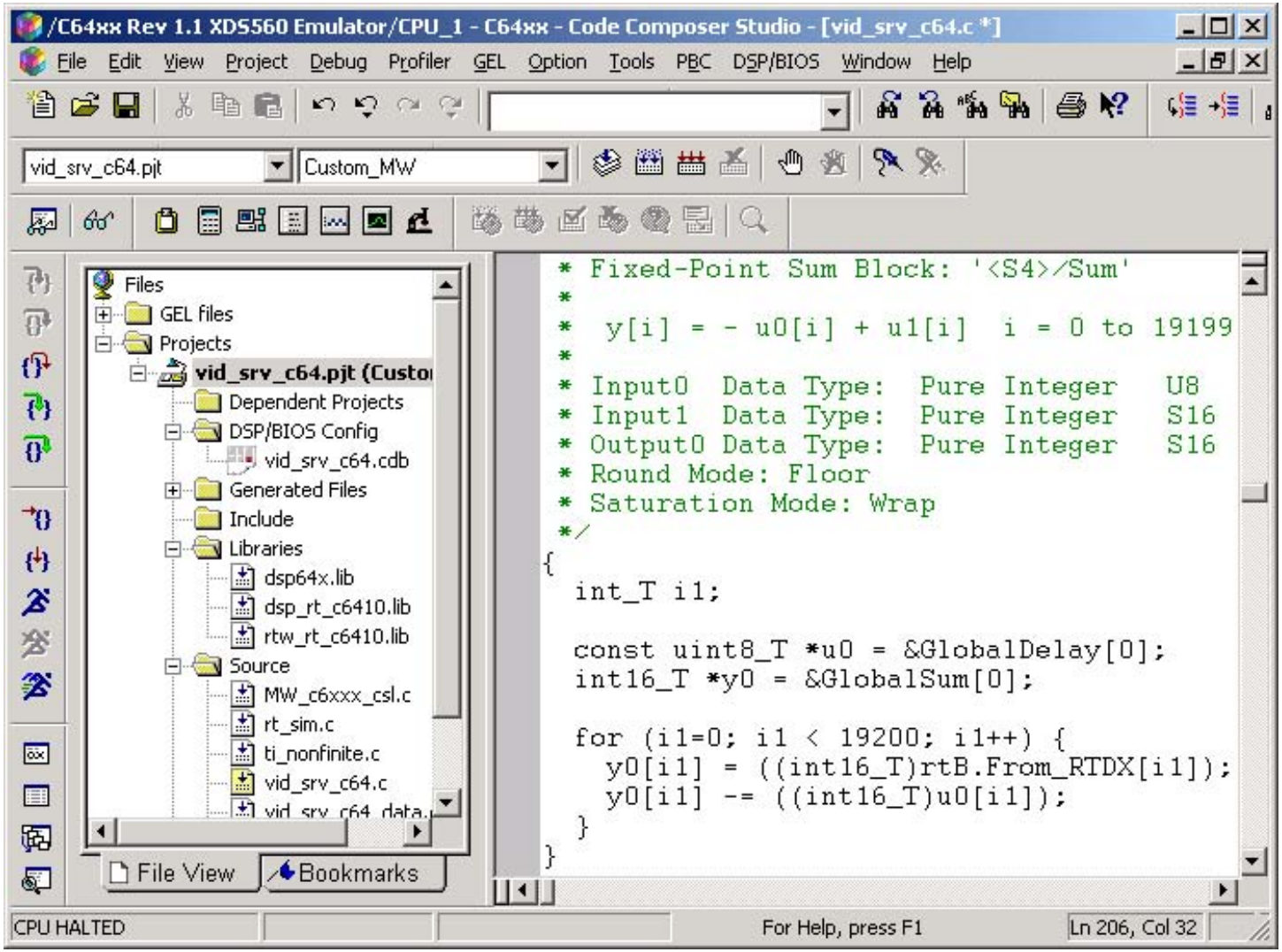




Steps to Target the TI C6416 DSP

3. Build process

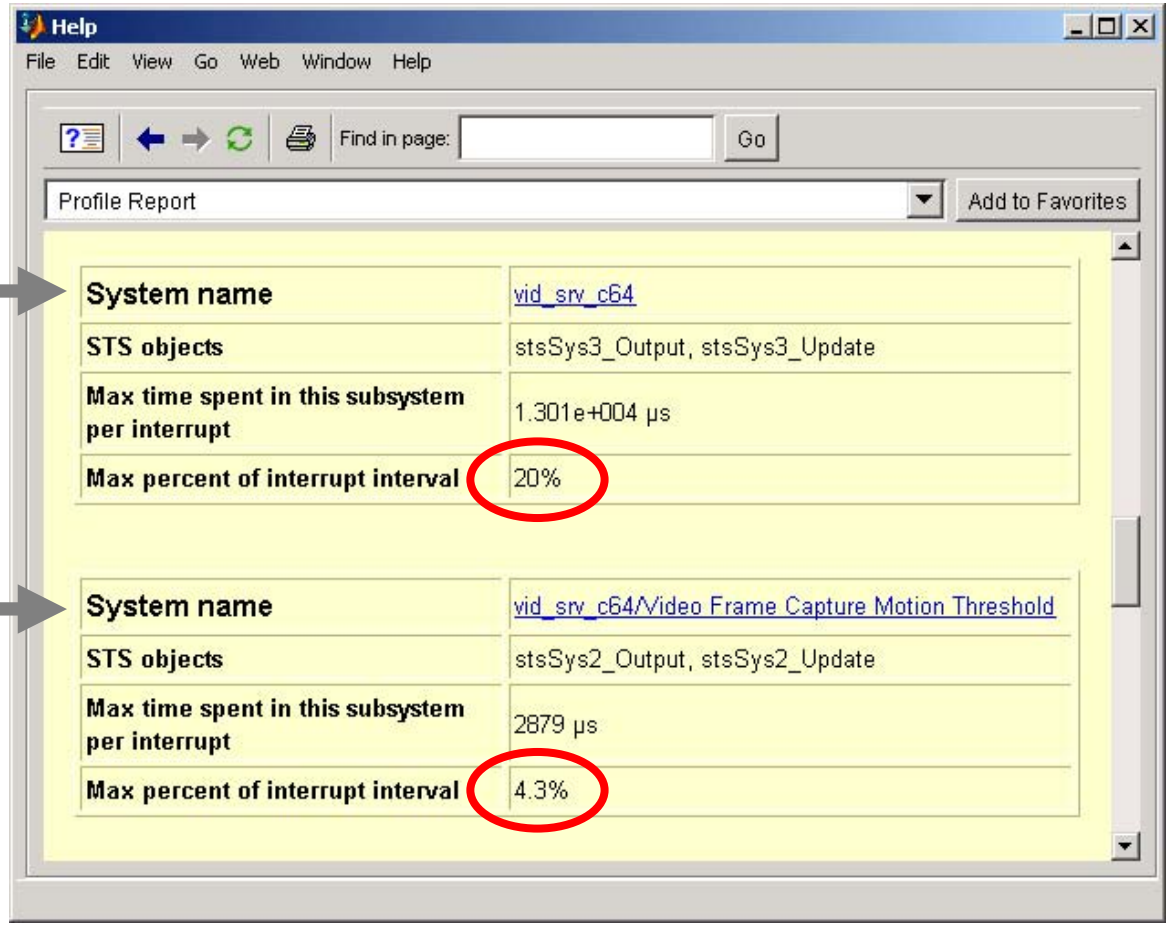
- Auto-generate ANSI C and ASM code
- Integration of RTOS and scheduler
- Create full CCS project in IDE
- Invoke compiler, linker, and download code
- Run target



Steps to Target the TI C6416 DSP

4. Automatic profiling of program executing on DSP

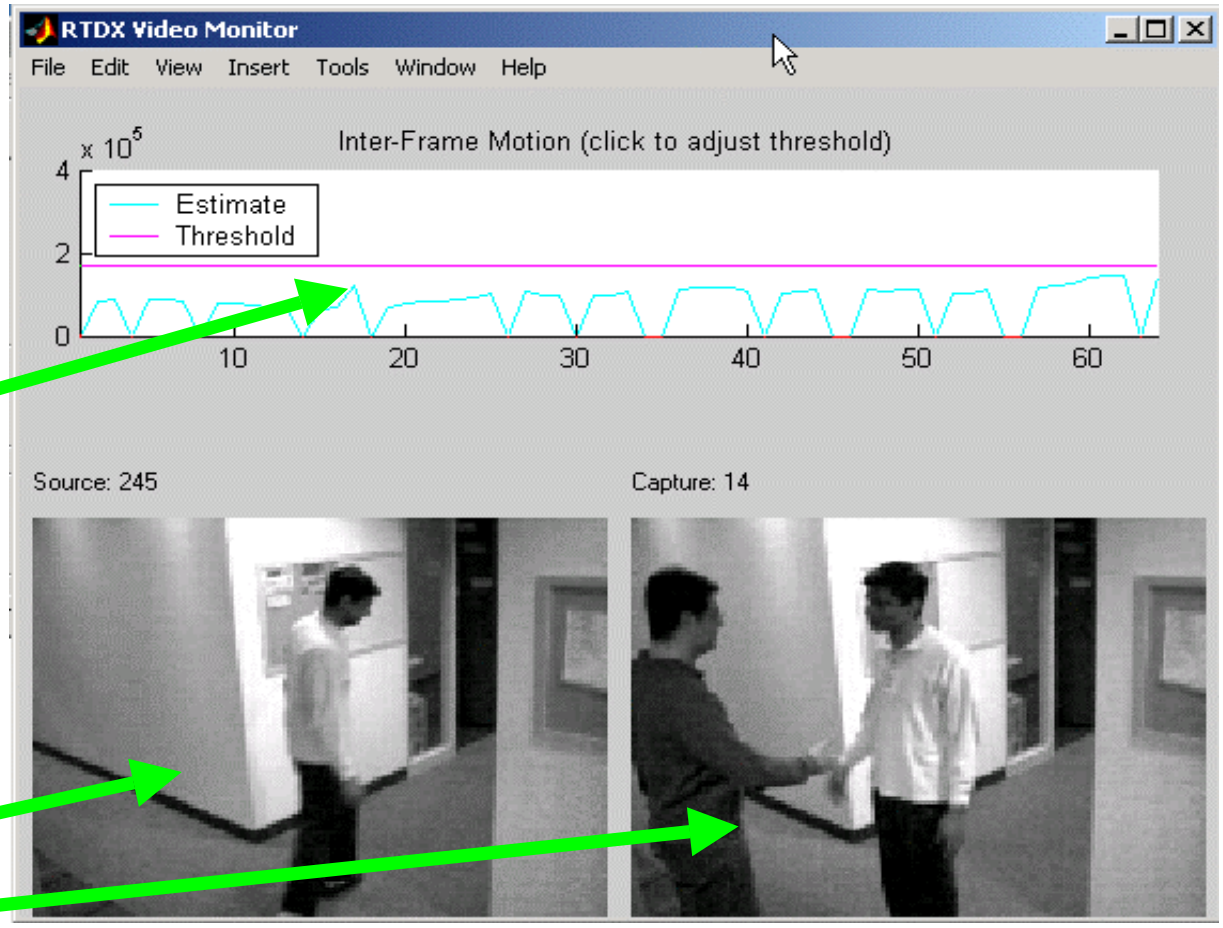
- **System profiling**
  - **Includes entire DSP application code**
- **Subsystem profiling**



Design Verification: Real-time Visualization

MATLAB Application

- **Host-side visualization**
- **MATLAB M-file GUI**
  - Using **Link for TI CCS** and standard Handle Graphics functionality
- **Motion Estimates**
  - Log and plot estimates over time (scrolling data)
  - Adjust detection threshold (click mouse on graph)
- **Monitor video capture**
  - Input video frames
  - Captured frames



Design Verification

Automating embedded software verification cycle

- **MATLAB Host Application uses *Link for TI CCS IDE* for communication with Code Composer Studio**
  - **Extends MATLAB language to interact with CCS**
  - **Provides project load/run/stop management, debug points, data manipulation, HIL, and co-simulation support**
  - **Supports real-time data exchange (RTDX)**
- **Use Link to visualize & verify correct behavior of code running on any TI DSP (C2000, C5000, C6000, OMAP, TMS470)**
- **Equips MATLAB with interactive DSP verification and test-bench validation capabilities**

Example CCS Link M-file

```
% Connect to CCS & DSP:
CCS_Obj = ccsdsp;
r = CCS_Obj.rtdx;

% Configure RTDX channels
r.open('vidIn',    'w', ...
       'vidOut',   'r', ...
       'motionEst','r');
CCS_Obj.run; % Run target app
r.enable;    % Enable RTDX chans

% Write data to DSP (real-time)
r.writemsg('vidIn', nextFrame);

% Read data from DSP
outFrame = r.readmsg('vidOut',
                     'uint8',[120 160]);
```

Summary: Simulink for Video Processing

- **Graphical block-diagram design environment**
  - Time-oriented, stream-based signal processing
  - Matrix-based, multi-rate, multi-tasking, frame-aware
  - Floating-point, fixed-point, and integer data types
  - Automatic code generation via Real-Time Workshop
  - Interoperability with MATLAB

Next Steps: FPGA Implementation

- Third-Party FPGA Design Products
  - Xilinx System Generator
  - Altera DSP Builder
- MathWorks HDL Products
  - Link for ModelSim™ (New: Oct'03)
  - HDL Filter Designer (Beta: Oct'03)

Next Steps: High Performance Video

- Fixed point enhancements to Simulink and MATLAB
- Image Acquisition Toolbox
- Video processing components (Beta: Jan'04)

Next Steps: For More Information

- Upcoming Simulink video processing webinar
  - www.mathworks.com/webinar_tid
- The MathWorks products
  - www.mathworks.com/products
- Additional Simulink video processing examples
  - www.matlabcentral.com

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Synopsis of Poster C.10

Poster C.10 - Thu 25 Sep 2003

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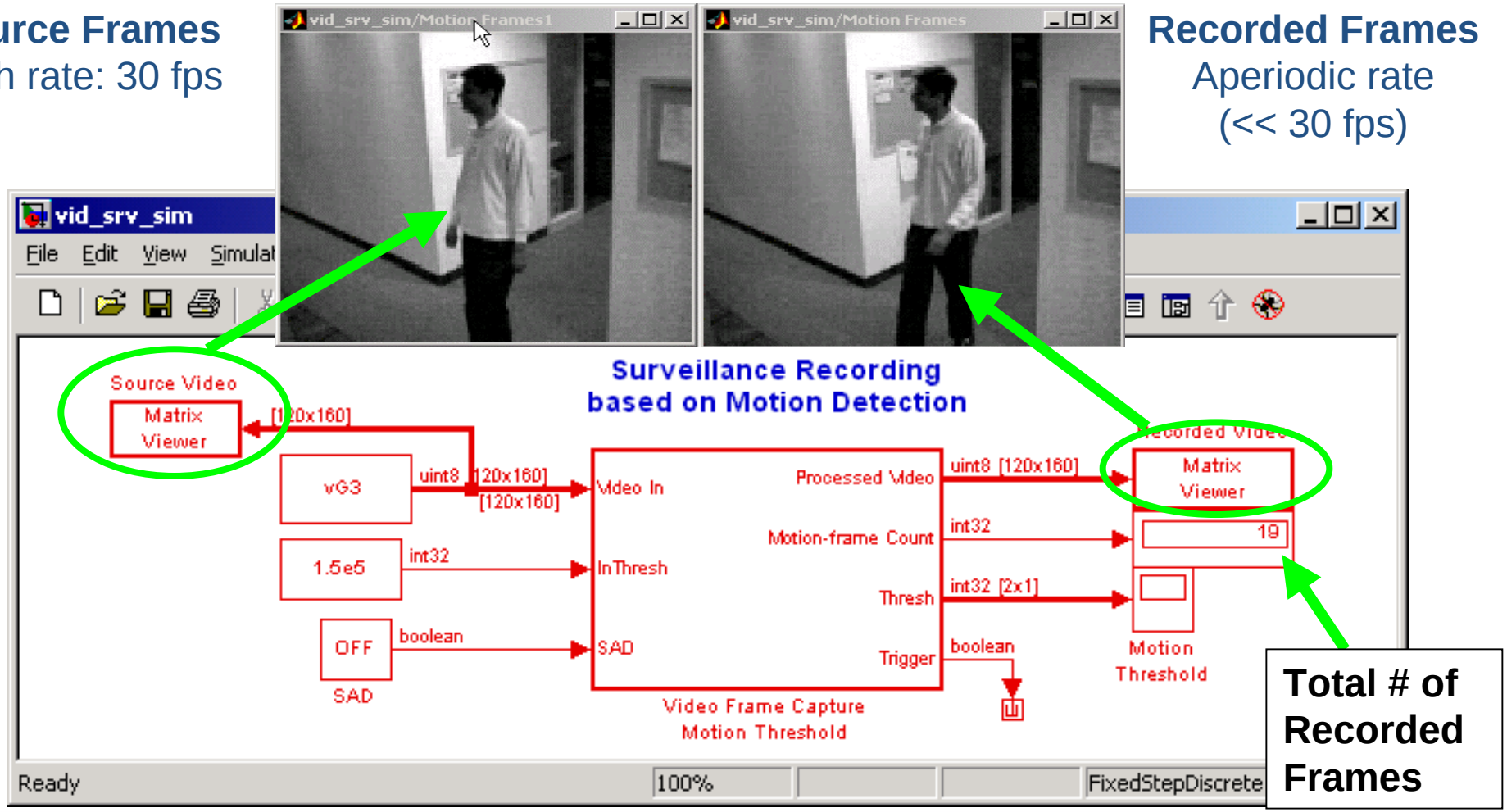
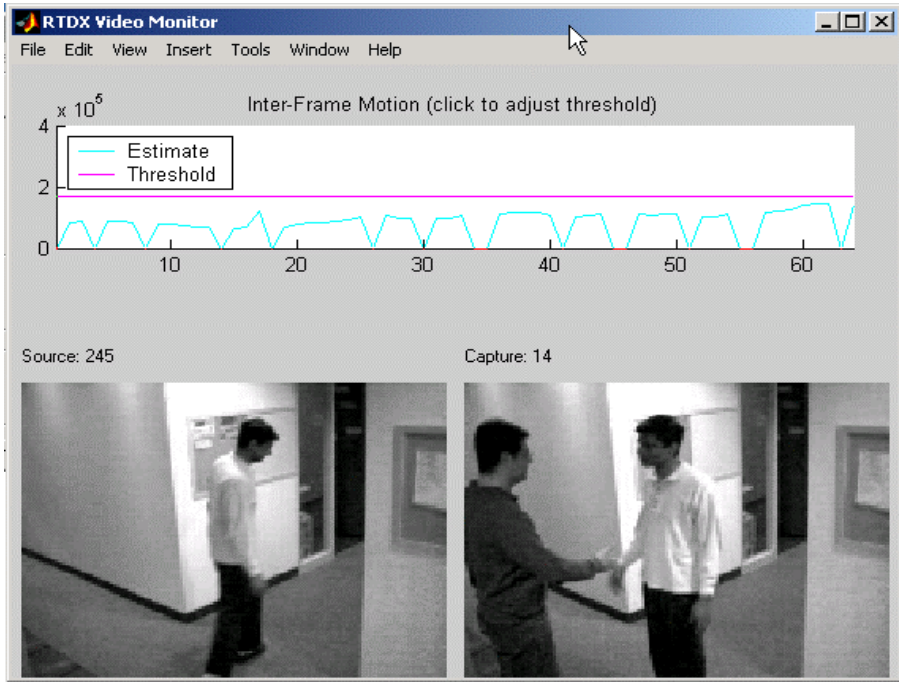


Total # of Recorded Frames

Video system demonstration

- **DSP running video application**
  - **"On-chip Rapid Prototyping"**
  - **TI C6416 DSK:** High-performance fixed-point DSP targeted by Simulink
- **MATLAB Host-side GUI**
  - Link for TI Code Composer Studio utilized for quick programming
  - Bi-directional data transfer for full-speed testing/visualization



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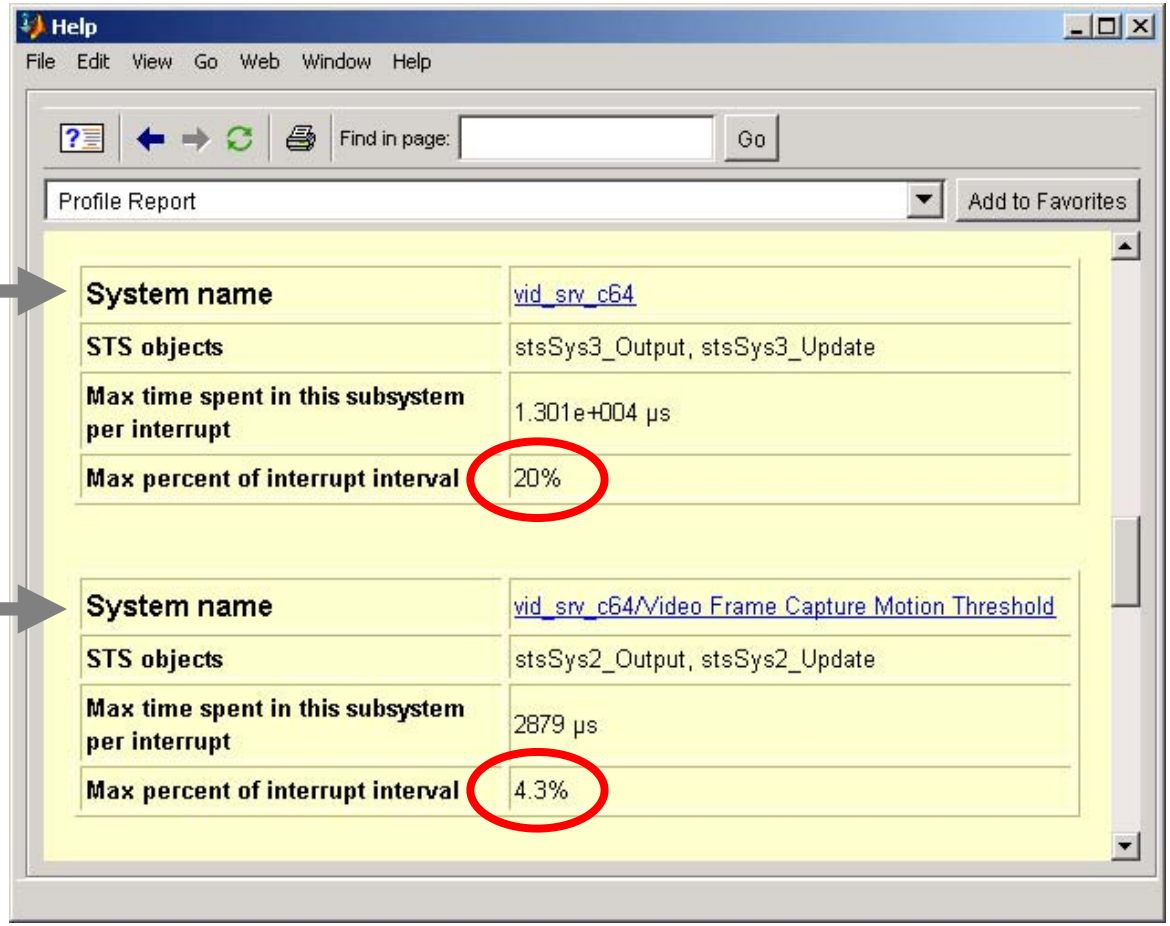

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Poster Panel Layout